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The Impact of Transportation Network Companies on Urban Transportation Systems

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The Impact of Transportation Network Companies on Urban Transportation Systems

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The Impact of Transportation Network Companies on Urban Transportation Systems

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This study uses a mixed-methods approach to investigate how Transportation Network Companies (TNCs) are impacting urban transportation systems. First, using survey and National Household Travel Survey data this study seeks to understand if TNCs are inducing travel demand. Second, using survey data this study analyzes what people value in regards to TNCs. Overall this study found that most people are using TNCs for occasional, weekend travel. For some portion of users TNCs may be inducing travel demand. This study also finds that most users value the convenience of TNCs. These findings imply that TNCs are not transforming urban transportation but are acting as supplemental transportation services.

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Chapter 1

Background

1.1 Introduction

In the decade since their founding transportation network companies (TNCs) have attracted almost hyperbolic levels of praise and criticism. Many have praised them as revolutionary services which are improving urban mobility [78]. But, critics charge that these services are exploiting their workers, aren't solving urban transportation problems and aren't revolutionary [78].

One of the reasons the rhetoric has grown so extreme is because there has very little empirical research about TNCs. Little is understood about how these services are impacting cities, particularly from a transportation planning perspective. Good data and solid analysis can hopefully bring a more nuanced perspective to the conversation about these services. By having a more through understanding of these services cities can have a more complete picture of what these services are doing to transportation systems and the urban fabric more broadly.

At a very high level this study aims to understand if TNCs are truly changing urban transportation systems by investigating how these services are being used.

More specifically this study investigates two questions. First, it examines how people are using TNCs, with a particular focus on if TNCs induce travel demand, which has been

the subject of much discussion [19]. Second, it investigates what people value about these services (e.g. convenience, price, travel time etc.) because little is currently understood about what makes TNCs 'better' from a consumer perceptive than conventional taxis, public transport etc.

This study proceeds as follows. First, background on TNCs, including their history is presented in order to ground the discussion. Second, a literature review is presented that explains what the state-of-the-art is in regards to TNC research. Third, the methods for this study are detailed followed by the results. Fourth and finally, an extensive discussion of the planning and policy implications of the findings is presented.

1.1.1 Definition

Before discussing TNCs in more depth it is critical that we understand what TNCs actually are. TNCs are often called a variety of things including ride-hailing services, ride-sharing services, ride-sourcing services, or e-hailing services. But not all these terms are interchangeable. Additionally, terms like ride-sharing can be inaccurate because they imply that these services are 'shared' between users when in fact the average occupancy of a TNC trip is about 1.1 persons (exclusive of the driver) [141].

According to the Federal Transit Administration (FTA), TNCs, are:

> online platforms to connect passengers with drivers and automate reservations, payments, and customer feedback. Riders can choose from a variety of service classes, including drivers who use personal, non-commercial, vehicles...and premium services with professional livery drivers and vehicles. Ridesourcing [TNCs] has become one of the most ubiquitous forms of shared mobility [59, para. 11]

As discussed above TNCs are distinct from ride-sharing services. The FTA defines ride-sharing as "adding passengers to a private trip in which driver and passengers share a destination" [59, para.10]. Currently, rarely do the TNC passenger and driver share a common destination therefore TNCs cannot truly be a ride-sharing service as currently constructed [106].

Even though drivers and passengers of TNCs rarely share destinations, many passengers often share trips between themselves through such services as Uber Pool and Lyft Line. The FTA provides another term to characterize these services namely "ride-splitting." Ride-splitting is "A type of [TNC] that [allows] customers requesting a ride for one or two passengers to be paired in real time with others traveling along a similar route" [59, para. 12].

Finally, TNCs are distinct from other services like carsharing and microtransit services which they are also often conflated with. Carsharing services are services that "[provide] members with access to an automobile for intervals of less than a day" [59, para.2]. Key is the fact that carsharing services (e.g. Car2Go, ZipCar etc.) only provide access to automobile and are not livery services. They require the user to drive themselves. Additionally, microtransit services are "private multi-passenger transportation services, such as Bridj, Chariot, Split, and Via, that serve passengers using dynamically generated routes" [60, para.5].

The next logical question is how are TNCs and conventional taxis any different? This, in many ways, is one of the most controversial aspects of TNCs. TNCs and their advocates claim that TNCs are different from taxis because they are fundamentally technology companies. According to Mariana Barbosa, legal director of Uber Brazil, companies like Uber are technology companies because "It is the driver that that hires Uber to run digital intermediation services" therefore Uber is not providing any transportation service, they are

merely providing the platform for drivers to connect to riders [20, para.6].

But, self-evidently TNCs and taxis provide the same essential service. They both offer people a ride from their origin to their desired destination in a car and users of these services are not expected nor allowed to drive themselves. In exchange users pay a fare that is determined largely by distance of the trip. In fact, TNCs and taxis are so similar that the European Court of Justice ruled that Uber is so similar to regular taxis that Uber must comply with existing transportation regulations for livery services [22]. In addition to being prima facia similar in nature, surveys "suggest that ridesourcing services and taxis serve a similar market demand—the plurality of ridesourcing users said they would otherwise have used a taxi for the same trip, and the two types of services covered similar areas and trip lengths" [128, pg.176]. In addition, the fact that TNCs have reduced the size and profitability of the taxi market further suggest that TNCs directly compete with taxis [162].

Despite these obvious similarities and the clear market overlap between TNCs and regular taxi service there do exist some key differences.

First, the general business model of TNCs is somewhat different especially in terms of how the relationship between the company and driver is managed. Traditionally cities have fixed the number of taxis that can operate in their city through a 'medallion' system [147]. A medallion gives the owner the right to operate a taxi. Companies than pay for these medallions and taxi drivers sublease the right to use the medallion for the duration of their shift [24, 147]. Additionally, conventional cab drivers generally lease the taxis they drive from the taxi company [163]. In contrast, TNC drivers typically own the cars they drive and do not operate under the medallion system, thus they are less formal than regular taxi services.

Second, users of these services interact with TNCs and taxis in a different manner. Users typically summon a TNC through the use of a smartphone app and cannot hail a TNC vehicle on the street. Taxis, however, can hailed on the street or sometimes through an app or by calling the taxi company directly. Finally, when users take a TNC everything is handled through the app including payment for the the ride and tipping. In a traditional taxi users must pay for the service in the cab using cash or a credit card.

Third, some researchers have demonstrated that TNCs are serving slightly different market segments than conventional taxis. For example, TNCs may offer users faster, cheaper, and more reliable service than traditional taxis and thus appeal to users to would not otherwise be using taxis [120]. Additionally, other researchers have argued that TNC riders would otherwise take public transport or drive instead of taking a taxi. This implies that TNCs and taxis may not be competing for the exact same market [128].

In summary, TNCs are fundamentally the same type of service as conventional taxi services; they offer a for-hire ride with a fare based mostly on distance of trip. But TNCs are different than conventional taxis because the app makes the transaction between the TNC and customer hassle-free [13].

1.1.2 History of TNCs

Having grounded our discussion about what exactly TNCs are, it is useful to take a look at where these services originated.

The very first TNCs began operations in 2007 but, neither Uber nor Lyft began life as a 'conventional TNC' as we understand them today [164]. The earliest iteration of Lyft was a service called Zimride which was founded by Logan Green and John Zimmer. This service

primarily focused on connecting people for carpooling purposes for long-distance trips [3]. Uber, initially focused on providing premium vehicle for hire services. They provided literally black, luxury cars like BMWs, Mercedes etc. to customers via an app [103].

However, around 2012 both Uber and Lyft began to shift their operations ways from their original business models and both companies launched their now standard services [3,103]. These services branded UberX and Lyft focused on offering low cost rides to people via a smartphone app. These services also shifted their focus to compete with taxis on price and not on the level of service offered.

After the initial roll-out of these services Uber and Lyft began to rapidly expand. By 2014 Uber had established itself in 100 cities worldwide [156]. Additionally by this time Uber had also secured tremendous venture capital funding and was valued at over $17 billion. By May of 2015 Uber was available in over 300 cities worldwide [156]. Lyft's growth, in contrast, was relatively slow and by 2017 it was available in 300 cities worldwide [3]. Additionally, by 2017 Lyft was worth only $7.5 billion, a small fraction of Uber's valuation.

In addition to Uber and Lyft, the third major TNC, today, is Didi Chuxing which was formed from the merger of two taxi companies, Didi Dache and Kuidai Dache [46]. Initial funding for both of these services was provided largely by e-commerce giant Alibaba and IT giant Tencent in 2012. At first these two companies were fierce rivals and competed for control of the lucrative Chinese ride-hail market. However, in 2014 Uber entered the Chinese market. Essentially, the competition from Uber motivated Didi Dache and Kuidai Dache to merge [46]. After the merger the newly rebranded Didi Chuxing was able to out-compete Uber and eventually it purchased Uber's China operations. Today Didi has an approximate valuation of ¥536 billion RMB or $80 billion USD. Didi is also slowly expanding its international

operations and now operates in Brazil, Mexico and Australia [18].

Finally, it is worth briefly mentioning that several other smaller ride-hailing companies have and/or do exist. Most notably Sidecar was briefly a third competitor to Uber and Lyft but went bankrupt in 2015 [115]. Additionally, several other much smaller TNCs such as Via and RideAustin are currently operating. However, these services have not, to date, obtained any significant marketshare.

1.1.3 TNCs Today

As discussed above TNCs service today is essentially a duopoly in most markets [72].Currently, Uber is the largest TNC is the world, followed by Chinese rival Didi Chuxing [50]. Uber dominates the North and South American, European, and Australian markets [18]. Didi on the other hand dominates the Chinese market. Lyft is much smaller than Uber, but still has a strong presence in the American and European markets [152].

In terms of services offered all of these companies are similar. Each company offers four levels of service as shown in Table 1.1. The names of each of these services is shown in Table 1.2. The most popular and basic level of service e.g. UberX, Didi Express etc. offer users a private ride in a standard, non-luxury vehicle such as a Toyota Prius and Honda Accord [45].

Each company also offers shared rides in standard vehicles. For shared rides the user may be expected to walk a short distance at the beginning or end of the trip to meet the driver [45].

Finally, each service provider offers a more premium tier of service e.g. Uber Select, Lyft Lux, Lyft Black etc. These services offer customers rides with drivers who have higher

than normal ratings. They also use premium cars such as BMWs, Lexus etc. [45, 85].

Table 1.1: Levels of Service Offered by TNCs

Type of Service	Definition
Ride Splitting Service	A ride that is shared with other passengers. Passengers may be expected to walk a small distance at the beginning or end of the trip. The cheapest service offered.
Standard Ride Service	Ride that is not shared with other passengers. The standard level of service for TNCs.
Semi-Premium Service	Ride that is not shared with other passengers. Offers a more premium service than the standard level of service. The vehicles are higher end and include BMWs, Land Rovers etc. Additionally, the drivers have to obtain a high rating to qualify to drive for this level of service.
Premium	The highest level of service offered by these companies. The cars are high end cars including BMW 5-series, Lexus LS etc. For Uber and Lyft the cars are black in color.

Table 1.2: Names of Services Offered by TNCs

Type of Service	Uber	Lyft	Didi
Ride Splitting Service	Uber Pool	Lyft Line	Didi Express Pool
Standard Ride Service	UberX	Lyft	Didi Express Select
Semi-Premium Service	Uber Select	Lyft Lux	Didi Express Select
Premium	Uber Lux	Lyft Black	Didi Premier

Pricing on these services varies substantially based on the level of service, time of day, 'surge' trip status, and distance traveled. As an example, in Table 1.3 the prices for each level of service for both Uber and Lyft are listed. These prices are for a non-surge trip on a Monday at 2:30 pm . The starting point for this trip is the University of Texas to the Texas State Capitol, an approximately 2 mile journey. As shown, the 'luxury' tier of service

in general is at least three times more expensive than the ride-splitting level of service and approximately twice as expensive as the standard level of service.

According to Uber surge pricing occurs when demand for rides is high such as during "bad weather, rush hour, [and/or] special events" which allows Uber to "continue to be a reliable choice" [157, para. 2-3]. Surge pricing generally causes rides to be about twice as expensive as normal, but some research has demonstrated that surge pricing can cause rides to be as much as six times as expensive as normal [90, 157]. However, surge pricing in general appears to be a relatively rare event overall. According to one study, in Chicago it occurred in less than 3% of all trips studied [142].

Table 1.3: Prices for 2 Mile Uber and Lyft Trips

Service Level	Name of of Service	Price
Ride-Splitting	Uber Pool	$4.87
	Lyft Line	$4.38
Standard Service	Uberx	$6.94
	Lyft	$6.39
Semi-Premium Service	Uber Select	$12.91
	Lyft Lux	$11.04
Premium Service	Uber Lux	$17.15
	Lyft Lux Black	$14.31

In summary, TNCs service can be summarized a duopoly in most markets around the world. They offer services that are relatively affordable but average fares are rising [127]. Their key competitive advantage, as discussed, is that their smartphone based apps are very easy to use and abstract away payment from the user.

Chapter 2

Literature Review

Overall, the research on TNCs is still incipient. Part of this is because these services are fairly new, having only been around for about a decade. The other reason for the relative dearth of literature is that for much of their existence TNCs have been reluctant to share data with researchers, however this is beginning to change [49, 87].

Despite these limitations researchers have been able to investigate several key aspects of TNC operations namely the affects of TNCs on travel behaviors, the economics of TNCs, the general usage patterns of TNCs, and to a lesser degree how users perceive and value these services.

2.1 Usage

The first area that has been studied is the general usage of TNCs. Essentially, researchers have attempted to understand how TNCs are being used, who is using TNCs and where TNCs are being used.

One of the first studies on TNC usage was conducted by Castiglione et al. in 2017. This study used API pinging, whereby "vehicle locations, estimated times-to-pickup, and sometimes, estimated costs" where collected by sending a request to the public facing Uber/Lyft APIs [30, pg.8]. This data was then used to impute the characteristics of TNC

travel in San Francisco, California.

Their goal was to understand how many TNCs are operating in San Francisco. They found that there are approximately 45,000 TNCs operating and "that 170,000 TNC vehicle trips are estimated to occur within San Francisco during a typical weekday. This represents approximately 15% of weekday trips" [30, pg.5]. They also found that most TNC trips occur during weekends, especially on Friday and Saturday nights, and that most of these trips occur in Downtown San Francisco.

Grahn et al. found that as population denisty increases, the usage of TNCs increased as well indicating that TNCs are probably mostly used in dense urban areas like the downtown areas of cities [66]. Dogtiev, in his comprehensive analysis of publicly available information about TNCs, estimated that there may be about 1.5 million TNC drivers in the United States as of 2017. He also found that the average trip in a TNC, nationwide costs about $12 [44].

Several studies have investigated how often they use TNCs. Circella et al. found that more than 60% of people in California have never used a TNC, although this varied by region. They also found that about a third of TNC users use a TNC between once a month and less than once a month [35]. Some of these findings were mirrored by Clewlow and Mishra who also found that about 60% of adults surveyed in the United States do not use TNCs [37]. Grahn and Harper also investigated how frequently people are using TNCs. They found that more than half of users use a TNC 3 time per month or less [66]. They also found that higher income households use TNCs with higher frequencies than lower income households. Finally, they found that 99% of very frequent users lived in urban areas [66].

2.2 Demographics

From the above literature it is clear that TNCs are not a frequent mode of transportation for most individuals, but who is using TNCs? What are the demographic characteristics of TNC users?

Generally speaking, according to one study, in general both Uber and Lyft users tend to skew female overall. About 52% of Uber users and 58% of Lyft users are women [44]. This finding is somewhat contradicted, however, by Grahn and Harper who found that TNC users skew about 52% male according to NHTS 2017 data [66]. An additional study also found that Uber users are more likely to be male [62].

In general, it is safe to say that TNC users are much more likely to be white, urban dwellers with higher incomes compared to non-users. In terms of age TNC users tend to be younger [35, 44, 66]. Several studies find that the plurality of TNC users are between 25-34 [35, 44]. Studies also find that most TNC users are white [66]. Studies are also in agreement that users of these services tend to be much more affluent than non-users. For example, Smith found that 26% of American's making $75,000 or more have per year used a TNC service compared to just 10% of people making less than $30,000 per year.

Researchers have also found that the demographics of drivers are different than those of users. According to an internal survey conducted by Uber, drivers are overwhelming male. Only 14% of drivers are female. About half of drivers are parents. 60% of Uber drivers are non-white. Additionally, the plurality of drivers are between 30-39, at 30% of all drivers. But in general 69% of Uber drivers work full-time at another job aside from driving for Uber [154]. They are also very likely (67% of drivers) to have not been professional drivers prior to their

experience with Uber. These findings are largely confirmed by other surveys of TNC drivers. According to a survey carried out by SurveyMonkey Intelligence about which means 60% of drivers are non-white [53]. This survey also found that there is no dominant age cohort among drivers [53]. Finally, this survey found that most drivers are part-time drivers.

2.3 Economics

The economics of TNCs both from an individual perspective and an industry wide perspective have also been studied by a number researchers. First, we will examine the overall economics for TNC drivers and what encourages them to drive for a TNC service.

According to a survey of Uber and Lyft drivers the average monthly earnings for drivers are $364 and $377 respectively [44]. This is roughly consistent with other sources who find that TNC drivers make between $8-$9 per hour when all expenses are accounted for. However, self-reported incomes tend be higher than this with some drivers reporting earnings as high as $20 per hour [5].

In general, there are three basic 'types' of drivers [9]. The first type of driver is an "incidental driver" who only occasionally drives for a TNC when they have free time or when they are traveling to a destination regardless. The second type of driver is a "part time" driver "who use the service to supplement income... part-timers are more likely to work... routine "shifts"...such as after work or on weekends" [9, pg.1106]. Finally there are "full time" drivers who "Attempt to use the service as a primary means of income...[they may take] rides over the entire course of the day, or [focus] on rush hours." Full time drivers also tend to work long hours, as much as 60 hours per week in some cases [9, pg.1107]. Overall, most TNC drivers tend to be part-time rather than full-time. According to one 2018 survey of

TNC drivers only about 26% of drivers derived all or nearly all of their income from driving for TNCs [5]. Having said that, most TNC drivers tend to drive for TNCs outside of normal '9-5' working hours. Chen et al., in a National Bureau of Economic Research paper, found that "drivers are more likely to be working Saturday afternoon and evening than a weekday afternoon or evening...this pattern of driving is the outcome of both supply and demand factors" [34, pg.10].

Finally, some literature has reviewed whether or not drivers are motivated by the convenience of driving for TNCs or by monetary reward. The research on this is largely split. Chen et al. found that "there appears to be a negative correlation between payout per minute and the share of drivers working. This suggests that payouts are high in periods where drivers have higher reservations wages and choose not to drive" [34, pg.15]. Chen concludes "flexibility will be an important source of value in such arrangements" [34, pg.29]. However, surveys of drivers have found that 55% of drivers report that pay is the most important factor when deciding whether to drive for a TNC or not [5]. Additionally, TNC drivers tend to have high turnover rates with about 60% or so of drivers becoming inactive after six months [40].

Research has shown that women tend to earn less than men on TNC platforms likely because men tend to work longer hours and have a longer tenure with TNC platforms, drive in more profitable locations, and drive faster. This study also finds that "Customers do not discriminate by gender of driver, there is not a financial return to work intensity within a period of time...[there is no] financial penalty for the specific hours [worked]" [40, pg.4].

In terms of the economics of TNCs for users, Schwieterman and Livingston found that TNCs save time, but are very costly in terms of the dollar spent per minute of time saved [142]. TNCs also tend to be the least cost competitive in areas where public transport is

the strongest i.e. Central Business District areas [142]. This makes sense as public transport competes best in dense areas of cities. Schwieterman also found that TNCs are very expensive on a per minute time savings basis [142].

Despite the relatively high prices no TNC company has turned a profit to date and at least one study has assessed whether TNCs can ever become a profitable enterprise or not. As of 2015, Uber operated at a profit margin of -143% [78]. Horan concludes, that despite assurances to the contrary, TNCs like Uber are unlikely to ever turn a profit. Horan argues that because Uber operates a decentralized platform it cannot achieve the efficient operations that make conventional taxis work. Additionally, Horan argues that Uber competes in the for-hire vehicle market by being a better taxi i.e. having more comfortable cars, more "professional" drivers etc. However, in order to maintain this high level of service Uber will have to pay high wages and compensate drivers for repairs of the cars and so on [78]. Thus, Horan argues that Uber will not "grow into profitability" [78, para.1].

In addition to researchers have examined the relationship between TNCs and broader economy; much of this research has been focused on the overall affects of TNCs on the taxi industry. Contreras and Paz estimated the affect of TNCs on the taxi industry in Las Vegas, Nevada. They found that TNCs have a negative impact on the number of taxi trips in Las Vegas and that " that the taxicab industry in Las Vegas, Nevada, has indeed taken a significant hit in ridership with the recent presence of [TNCs]" [39, pg.69]. In a very similar study the impact of TNCs on the taxi cab industry in Chicago and New York was tested. This study also found that an increase in the number of Uber trips specifically, correlated with less taxi cab trips in New York (no data on taxi trips was available for Chicago) [162].

The introduction of TNCs also decreases taxi driver wages, which makes intuitive

sense. At least one study modeled the impact of Uber introduction on taxi driver wages in Metropolitan Statistical Areas (MSAs) across the United States [16] This study found that Uber's introduction into a MSA led to reduce earnings for taxi drivers. Additionally, this study found that this loss of earning was unique to taxi drivers and was not found "among workers in other broadly similar transport occupations" [16, pg.206]. Again, this and the other studies outlined above all strongly suggest that TNCs are having a negative impact on the taxi industry.

One intuitive reason that the taxi industry is suffering due to TNCs is that taxis and TNCs serve similar markets; several studies have looked at the service and usage differences between conventional taxis and TNCs. One study conducted in metropolitan Milan, the Philippines compared various performance indicators of taxis and TNCs, using survey data collected from regular users of "Uber, GrabCar [a carsharing service], and Conventional Taxi [sic]" [120, pg.1]. This study found several interesting things. First, it found that Uber vehicles had an average travel speed of 21.3 km/hr compared to just 12.9 km/hr for conventional taxis. They also found that Uber cost about ₱20 per kilometer compared to ₱28 per kilometer for a conventional taxi. Finally, the found that Uber had the highest quality of service rating by users on a 1-5 Likert Scale with an average rating of 4.8 compared to 3.9 for conventional taxis [120]. Overall, this study found that Uber provides better service than conventional taxis. However, this study also finds that "Uber [does not adhere to] the ridesharing principles. It performs similar to a conventional taxi with premium service that has a predetermined booking" and that "TNCs [overlap] with [conventional] taxi services as these both use non-commercial vehicles for public transport" [120, pg.9].

Another similar study conducted by Lisa Rayle et al. compared taxi and TNC trips

and user characteristics in San Francisco. This study also relied on surveys of TNC users. This study found that TNC trips are more evenly distributed throughout the city than conventional taxi trips which tend to be concentrated in the CBD. Although the authors do note that they "lack data on the overall spatial distribution of [TNC] trips" and thus " cannot say how representative [the] data are" [129, pg.9]. They also found that taxi trips had higher average occupancy than TNC trips. In a finding that is similar to that of the Manila study, Rayle et al., found that TNCs provide quicker service with wait time that are "dramatically shorter than typical taxi dispatch and hail times" [129, pg.12].

Overall, the two studies largely come to the same conclusions, finding that "[TNCs] and taxis serve a similar market demand: the plurality of [TNC] users said they would otherwise have used a taxi for the same trip, and the trips covered similar areas and trip lengths" [129, pg.18]. Additionally, this study also confirms the findings that TNC generally provide higher levels of service to their users with both more consistent and quicker service as compared to conventional taxis.

2.4 Travel Behavior

A number of studies have examined the impact of TNCs on people's travel behavior especially Vehicle Miles Traveled (VMTs). Clelow and Mishra used a survey to assess people's travel behavior and the relationship between TNCs and said behavior. They found that among those who use TNCs infrequently, i.e. a few times a month or less, the majority of people did not reduce their personal VMTs because of their usage of TNCs. However, among those who used TNCs once a week or more, over half of people reduced their personal VMTs. There was a also a clear trend between frequency of TNC usage and reduction in personal

VMTs. Among the most frequent users of TNCs, those who used TNCs daily, 53% of them reduced their personal VMTs by 50 miles or more. However, the authors here are quick to note that this reduction in VMTs is only for personal VMTs and not net VMTs. In fact the authors state that the personal VMTs reduced "return in the form of miles traveled in a [TNC] vehicle" and that within the context of their study it is not possible to quantify the net effect of TNC services on VMTs [37, pg.22].

Other studies have attempted to quantify the net impact of TNC services on VMTs in cities. Henao and Marshall used an innovative approach to collect data on TNC trips in the Denver metro area by actually driving for Uber and Lyft and by administering surveys to passengers in their vehicles. Overall, they collected data on 416 trips split between a variety of Uber and Lyft modes. They found that the existence of TNCs likely add "83.5% more VMT to the system than if these services did not exist" [73, pg.18]. The increased VMTs were due to a variety of factors especially induced travel demand, 'deadhead' miles 9(from the driver of the TNC having to drive without passengers), and mode replacement (34% of TNC trips would have been waling, biking or transit if a TNC wasn't available) [73]. These results strongly suggest that TNCs are adding to congestion issues instead of reducing them. These results are largely confirmed by the findings of Schaller, who found that TNCs created 976 million additional VMTs in New York City between 2013 and 2017 [141]. Likewise another study that looked at TNCs in Los Angeles, California and Seattle, Washington found that TNC vehicles were being utilized as TNCs about 60% of the time over the course of a drivers shift [42]. Despite the fact that this is a higher utilization rate than a conventional taxi, this finding seems to confirm the idea that TNCs have significant deadhead miles associated with them that are likely increasing net VMTs.

Despite some research being on the impact of TNCs on VMTs there has been very little empirical research done on the impact of TNCs on travel demand. In theory, if TNCs are providing users with a more convenient transportation option they might be inducing travel demand especially among those who do not own cars.

The two main studies that have directly examined the impact of TNCs on induced travel demand have been Henano and Marshall and Clewlow and Mishra. In Henano and Marshall, the details of which are discussed in the proceeding paragraph, the authors find that "more than 12% of ride-hailing rides would not have been taken had Uber and Lyft not existed" which suggests that there is real induced travel demand from TNCs [73, pg.8]. Clewlow and Mishra also assess the impact of TNCs on induced. Their survey found 22% of respondents would not have made their trip if a TNC had not been available [37]. Finally, there is a brief discussion of induced travel demand in Rayle et al. in which they find that 8% of people would not have made the trip if a TNC had not been available, which according to Rayle et al. suggests that "[TNCs induce] a small but not inconsequential amount of travel" [128, pg.174]. However, overall the relationship between TNCs and induced travel is significantly under-researched and remains unclear. Part of the reason for this is because TNCs are still a relatively new, although rapidly maturing form of transportation.

2.5 Values and Perceptions of TNCs

Very little research has been done on how people are valuing TNCs, especially as compared to other services such as public transport, driving alone, and conventional taxis. Many of the studies which have looked at people's values and perceptions of TNCs have focused much more on the 'shared economy' not TNCs specifically. The shared economy is

broadly defined as a system of transaction in which "consumers [grant] each other temporary access to under-utilized physical assets ("idle capacity"), possibly for money" [58, pg.5].

Belotti et al. looked at why users choose to engage with the shared economy. The research team conducted 43 interviews with users of shared economy services. They also interviewed a number of providers of shared economy services. This study found that users are primarily motivated to use these services to make social connections and because they are interested and/or curious about the services [14]. However, beyond merely using services for broader, social reasons Belotti found that users are most motivated by their desires for convenience and their desire to obtain the good or service on offer [14]. This study also found that service providers have a strong belief that they are making the world a better place by providing these services [14]. Zhu et al. also examined consumer motivations for using online services. They surveyed 314 people in Beijing, China. This study largely confirms the previous study in that it found "that functional usefulness is the fundamental value for consumers in adopting [online services]" [166, pg.2234]. This study also found that "emotional enjoyment and social identification...are appealing to users of [online services]" [166, pg.2234].

Chapter 3

Methods

This paper uses a mixed methods approach to answer several important under-research questions. These questions are:

1. How are people using TNCs?
2. Are TNCs inducing more travel demand, especially as compared to other shared mobility services?
3. What is motivating people to use TNCs especially with regards to level of service factors?
4. How do people value these services especially compared to other similar transport services?

3.1 Survey Methods

The first data-set this paper analyzes is a survey conducted in two parts. This survey is used to understand how people are valuing TNCs and also to understand how people are using TNCs. In the first phase of the survey I collected qualitative, survey data using a 'snowball' sampling technique. Snowball sampling is a research technique in which "research participants are asked to assist researchers in identifying other potential subjects" [2, para.1].

The author's family, friends and various acquaintances of the Urban Information Lab (UIL) were recruited to be part of the survey.

The survey was given to each participant via an email link. The respondents then took the survey using the Qualtrics online survey platform. Results were recorded electronically.

Second, the results of the above survey were used to inform the design of a professionally conducted panel survey. Some of the wording was changed slightly between the two surveys based on feedback from participants.

The second survey was a panel based survey collected by the professional survey firm QuestionPro. Participants responded to the survey questions either online or using the Questionpro mobile apps.

All of the survey responses were collected from eligible participants in the four larges Metropolitan Statistical Areas (MSAs) in the State of Texas, namely Austin, Dallas, Houston, and San Antonio. Figure 3.1 displays the areas that were eligible to be include in this survey. In addition to having to to live in one of these areas to be included in the survey, respondents needed to be above the age of 18 and to have had used a TNC in the past. A screening question was used to ascertain if the respondents had used a TNC in the past.

3.2 NHTS Methods

The second data-set that was used in the National Household Travel Survey circa 2017. The overall objective of this section of the study was to develop models that would predict trip-making activity based on a person's usage of shared mobility services.

The NHTS is a "periodic" survey conducted by the Federal Highway Administration in

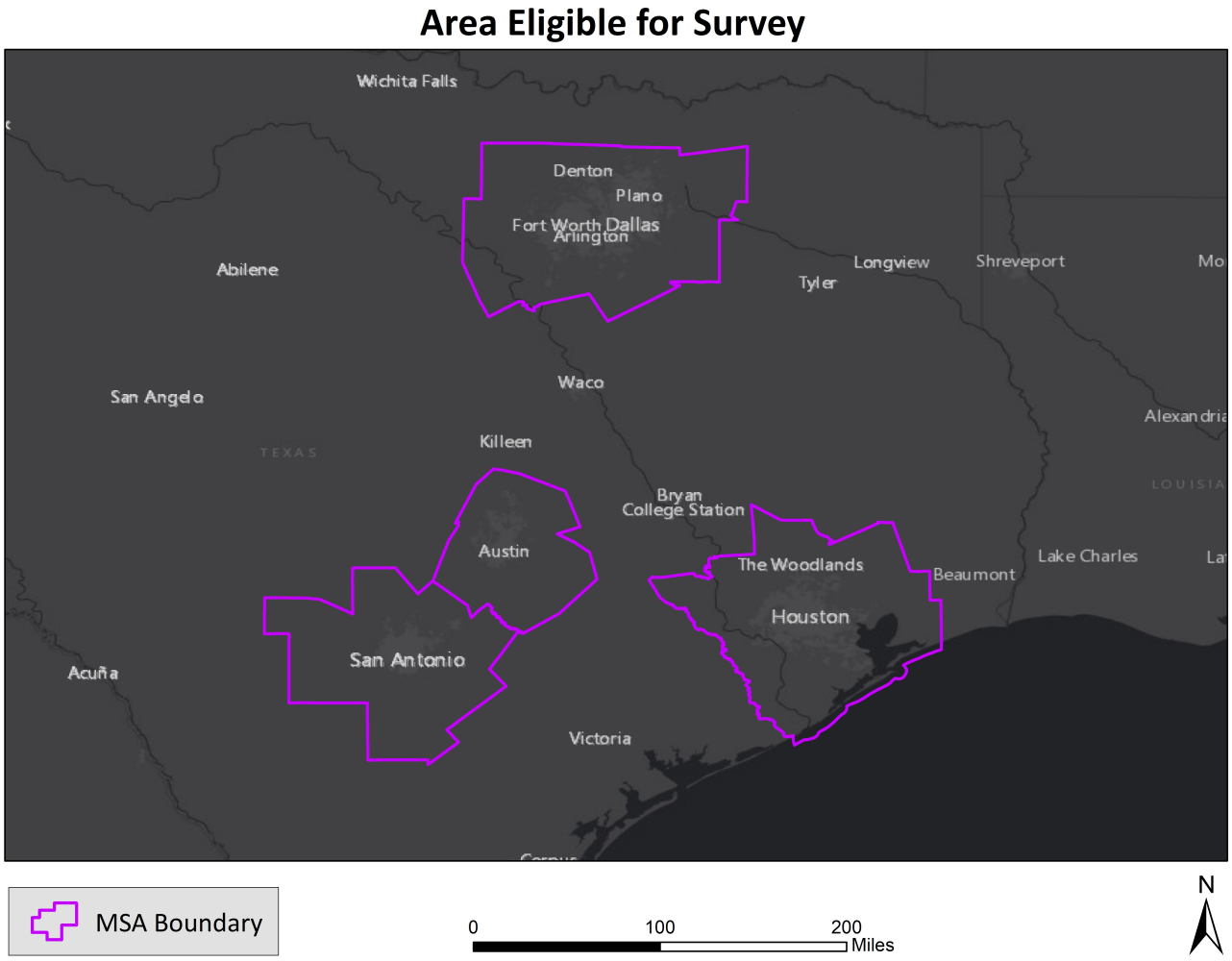

Figure 3.1: Map of Eligible Areas for Survey

which households are surveyed in order to understand travel behaviors in the United States [4]. New, in 2017, the NHTS began to ask respondents about their usage of shared mobility services such as bikesharing, carsharing, ride-hailing services [60]. The NHTS surveyed just over 129,112 households [54]. 26,000 of these households were sampled, randomly from across the US and the remainder were sampled from thirteen states or MPOs including:

- Arizona
- California
- Georgia
- Maryland
- New York State
- North Carolina
- South Carolina
- Texas
- Wisconsin
- Des Moines Area MPO
- Indian Nations Council of Governments in Oklahoma
- Iowa Northland Regional Council of Governments
- North Central Texas Council of Governments [54]

The NHTS records the number of trips a person made on the travel day and three key variables for shared mobility services which are shown in Table 3.1.

Table 3.1: Shared Mobility Variables in NHTS Dataset

Variable	Description
RIDESHARE	Subjects were asked how many times in the past 30 days they purchased a ride with a ridesharing app e.g. Uber and Lyft
BIKESHARE	Count of Bike Share Program Usage in Past 30 Days
CARSHARE	Subjects were asked how many times in the past 30 days they used a car sharing service e.g. ZipCar and Car2Go

3.2.1 Data-set Specification

The NHTS includes 200,000 data points [54], but restrictions were placed on this data-set for final analysis.

First, any person under the age of 18 was excluded from the final analysis. This is because official Uber states that "rider must be at least 18 years of age to have an Uber account and request rides" [158]. The same is true of Lyft which states that " [the] Lyft Platform is not available to children (persons under the age of 18)" [86]. Thus, in order to study only people who could be using the platforms we excluded anyone under the age of 18.

Second, in the final analysis we excluded any person who took zero trips on the travel day surveyed. In general, this was done because the objective of this study was to understand how shared mobility services are impacting people's normal trip making behaviors. Taking zero trips is unusual and, in fact, the NHTS asks respondents why they took zero trips on the travel day. These reasons range from being personally sick, to having a sick child, to being

on vacation [4]. While some of the reasons might indicate that a person's normal behavior is to take zero trips such as being home-bound, the average American takes about 4.1 trips per day [1] and thus zero trips can safely be classified as being unusual. Therefore, zero trip persons were excluded from our final analysis.

Third, an outlier analysis was conducted to determine if any persons were taking an usually high number of trips which might have skewed the results in some manner. The best practices outlined in Aguinis et al. were used to ascertain if data points, particularly data points concerning the number of individuals took were outliers. The data was visually and manually inspected to understand if any people took an unjustifiably high number of trips in the data-set. This is shown in Figures 3.2 and 3.3.

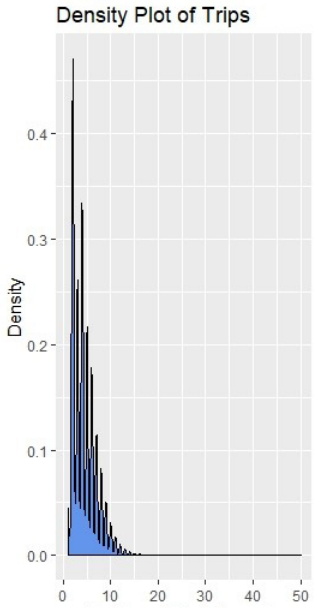

Figure 3.2: Number of Trips on Weekdays in the NHTS 2017 Dataset

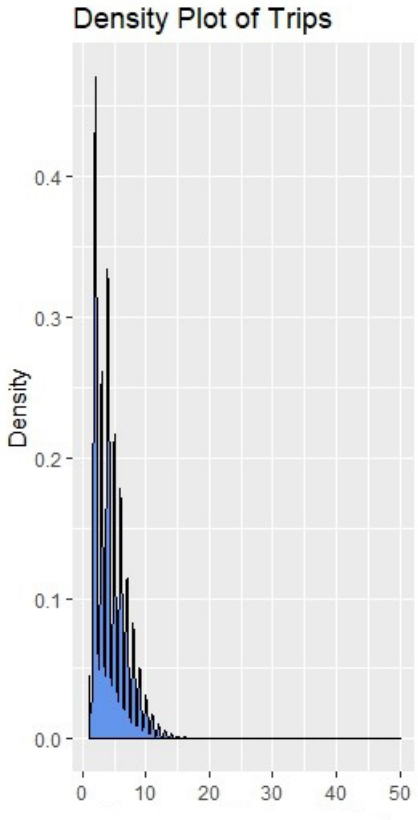

Figure 3.3: Number of Trips on Weekends in the NHTS 2017 Dataset

Based on the inspection it was determined that no person took an unjustifiably high number of trips during either of time periods and thus I opted not to exclude any records as outliers. This is in keeping with best practices in which data should not be automatically excluded as being an outlier if possible [8].

3.2.2 Model Development

After all the data cleaning and specification was done Negative Binomial (NB) models were developed to understand the impact of shared mobility services on trip making behavior. The independent variable was the number of trips a person took on a given weekday. The dependent variables used are are displayed below in Table 3.2. Variables that might impact the number of trips a person takes in a given day were selected. All analysis was performed in R version 3.5.2 using the "MASS" package and the glm.nb functions among others [134].

NB regression were used because in general NB models (or Poisson models) are used to analyze count data i.e data-sets which contain only positive values [61, 67, 68, 76]. Briefly the possibility that Poisson models could be used was consider, however, after performing log-likelihood ratio tests between the two types of models it was determined that NB models provided a better fit.

The variables used in the model are outlined in Table 3.2

Table 3.2: Variables used in NB Model Estimation

Variable Name	Type	Description
R_AGE	Numeric	The age of the person in years
EDUC	Ordinal	Education status of the person
WRK_HOME	Dummy	Dummy variable that takes a 1 if the person works from home and 0 otherwise
CARSHARE	Numeric	Number of times the person used a carsharing service in the last month
BIKESHARE	Numeric	Number of times the person used a bikesharing app in the last month
RIDESHARE	Numeric	Number of times the person used a ridesharing app in the last month
TIMETOWK	Numeric	Time to work for the person
HEALTH	Ordinal	Self-reports health status of the person ranked on a scale of 1 'Excellent' to 5 'Poor'
HBPPOPDN	Numeric	Population Density of the Census Tract where the person resides
WORKER	Dummy	Dummy Variable equal to 1 if the person is a worker (or full time student) and zero otherwise
URBRUR	Dummy	Dummy variable equal to 1 if the person lives in an urban area and 0 if they live in a rural area
HHFAMINC	Ordinal	Household income for person. Takes values ranging from 1 for less than $10,000 upto 11 for 200,000+$
DRIVER	Dummy	Dummy variable that takes a 1 if the person drove a car during the travel day and zero otherwise
MALE	Dummy	Dummy variable equal to 1 for males and 0 for females
FULL_TIME	Dummy	Dummy variable equal to 1 if the person is a full time worker and 0 if a part-time work or non-worker

Chapter 4

Results

4.1 Snowball Survey Results

For the snowball survey we collected 375 responses. The data was then cleaned to remove any incomplete or invalid responses which left 270 valid responses. Most of these invalid responses were because users started the survey but never answered all the questions.

The results were then analyzed from the perspectives of demographics, usage patterns, and preferences.

4.1.1 Snowball Demographics

Demographic details are displayed below in Table 4.1. Most of the respondents are between the ages of 45 and 18, but no single age cohort was dominant. A plurality (22%) of users were between 18 and 22 with the next biggest group those between 26 and 30. The smallest age cohort was for those 55+. In terms of ethnicity the majority of respondents, 61.2%, were white. The next largest group was Asian or Pacific Islander at 18.7%, followed by Hispanic or Latino at 14.2% of the survey takers. Finally, the respondents skewed female with 61.2% of the survey takers indicating they were female and 38.8% of survey takers indicating they were male.

In terms of income and education the respondents to this survey had a clearly bi-modal

distribution. This reflects the fact this survey was distributed among students and white collar professionals. 39.9% of the respondents indicated that they made less than $25,000 dollars last year, these respondents were likely mostly students. However, we also see that a fairly large percentage of respondents (11.5%) made $150,000+ last year there were likely white collar professionals. Such a dichotomy is also reflected in the fact that many of respondents were well educated. Fully 28.4% of respondents had a Bachelors Degree and 18.3% of respondents had a Doctoral or Professional Degree which is well above the national average. In the United States as a whole about 12% of adults 18 and over have an advanced degree (masters, professional, or doctoral degree) [138]. So overall our sample for the snowball survey reflects a demographic group that is highly educated and high earning or is on their way to being well educated with many of respondents being current students.

4.1.2 Usage Characteristics

Next we assessed the overall usage characteristics of our respondents in the snowball survey. For these questions we wanted to understand what types of trips respondents were taking and when they were taking them. We asked respondents' primary day of the week they used TNCs was, what time of day they used TNCs etc. The results are displayed in Table 4.2.

From the results it is clear that most TNC users are using these services for occasional, recreational travel that takes place largely on non-work day evenings. We can that the plurality of users use TNCs less than once a month and that the vast majority (88.5%) of users use TNCs a few times a month or less. This indicates that, as research has shown most users are infrequent users or use TNCs for infrequent travel. We also see that most

use responded that they use them for trips during weekends/non-work days. Futhermore, the two most common times to use TNCs were evenings (8 pm - 10 pm) and Night (11 pm - 1 am). This all makes sense in light of the fact that 72% of respondents said that they use TNCs for trips to bars, restaurants or other entertainment venues which was the most popular response. Finally, in terms of usage characteristics we see that most TNC trips are of a medium distance, between 10 - 15 minutes in length.

4.1.3 Perceptions of Services

We also asked users what they most valued when using TNCs and the results are displayed in Figures 4.1 and 4.2.

In terms of the relative importance of the five key factors we asked about respondents, considered reliability and safety the two most important factors in TNC usage. The least important factor was comfort.

In terms what motivated users to choose TNC services, by far the most important factor was convenience, with 64% of respondents choosing that as the main reason for choosing to use TNCs. Aside from 'other' the least important factor was ranked as travel time among respondents to the snowball survey.

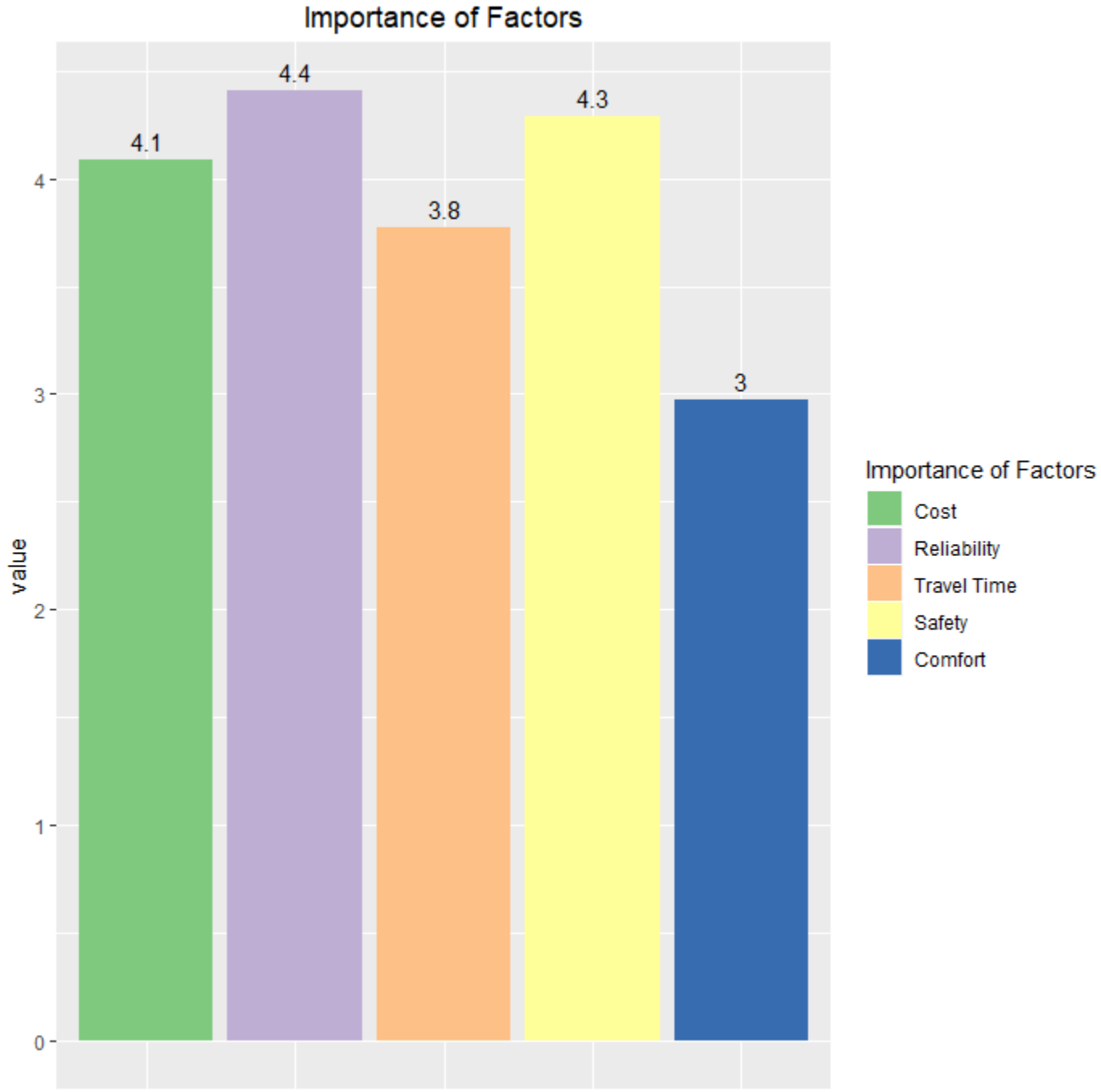

Figure 4.1: Ratings of Various Importance Factors for TNCs for Snowball Survey

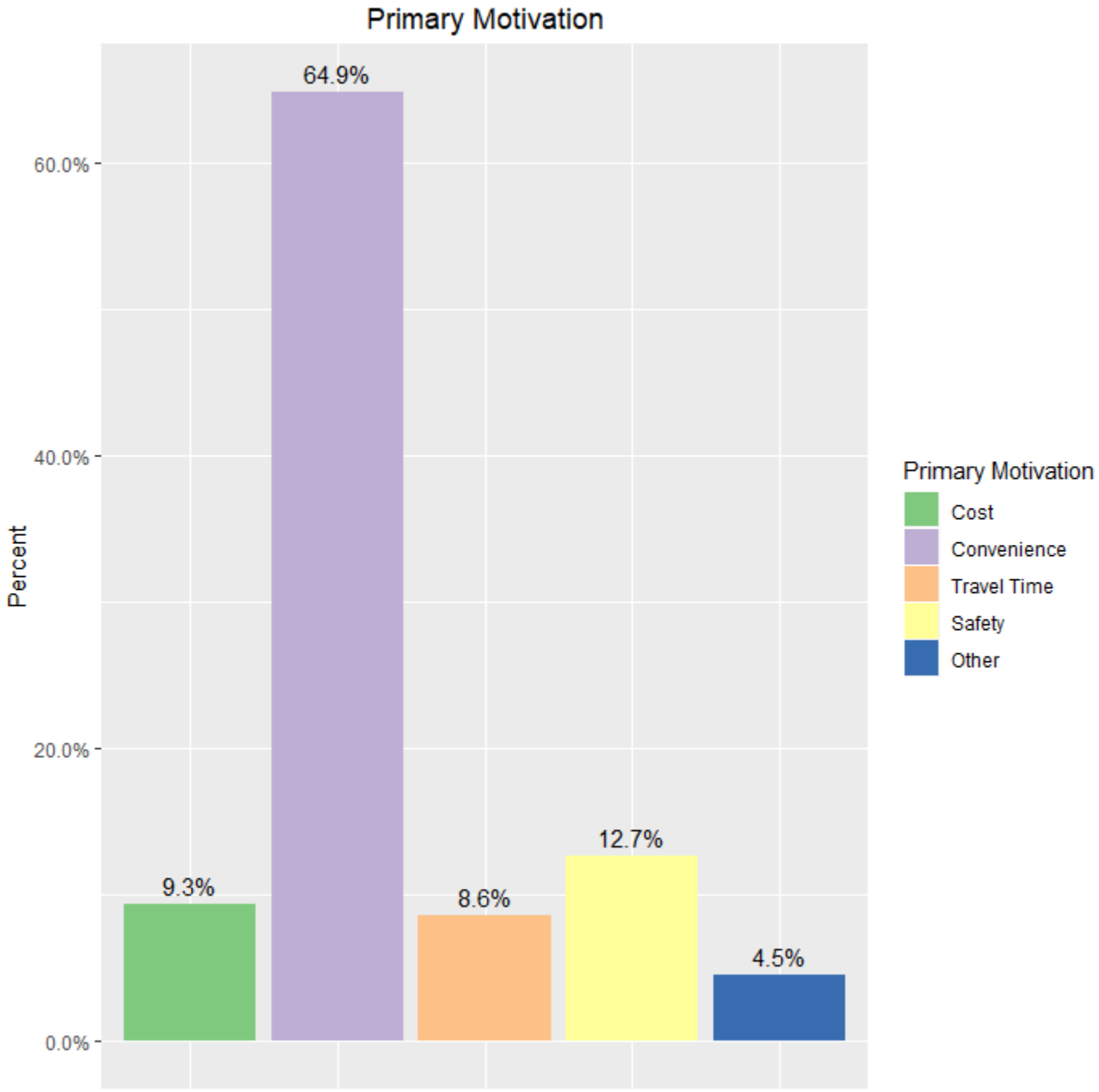

Figure 4.2: Motivation for Using TNCs in the Snowball Survey

4.1.4 Comparison to Other Transportation Services

We also tried to understand individual's motivation for choosing to use TNC by asking them to compare the service provided by TNCs to public transport and conventional taxis. The results are shown in Table 4.3.

Overall, the biggest theme emerging from the data is that respondents think that TNCs are more convenient as compared to both conventional taxis and public transport. About 82% of respondents thought that TNCs were more convenient than both public transport and conventional taxis. Additionally, a plurality of people responded that TNCs are both more reliable and less expensive than taxis and public transport. A majority of people did note that they felt TNCs were more expensive than public transport. In terms of TNCs relationship to other transportation services we can see that most respondents stated that they do not use these services to connect to other modes of transportation and when they do they most frequently connect to the airport and not another more quotidian transportation mode like a rail or bus line.

4.1.5 Perceived Trip Generation

Lastly our snowball survey asked users if they believed that TNCs induced them to make more trips. These results are shown in Figures 4.4 and 4.3. We can see that a slight plurality of people responded that TNCs helped them get more places. However, the more interesting result is that in the snowball survey most people (59%) stated that they believed that TNCs did not cause them to make more trips.

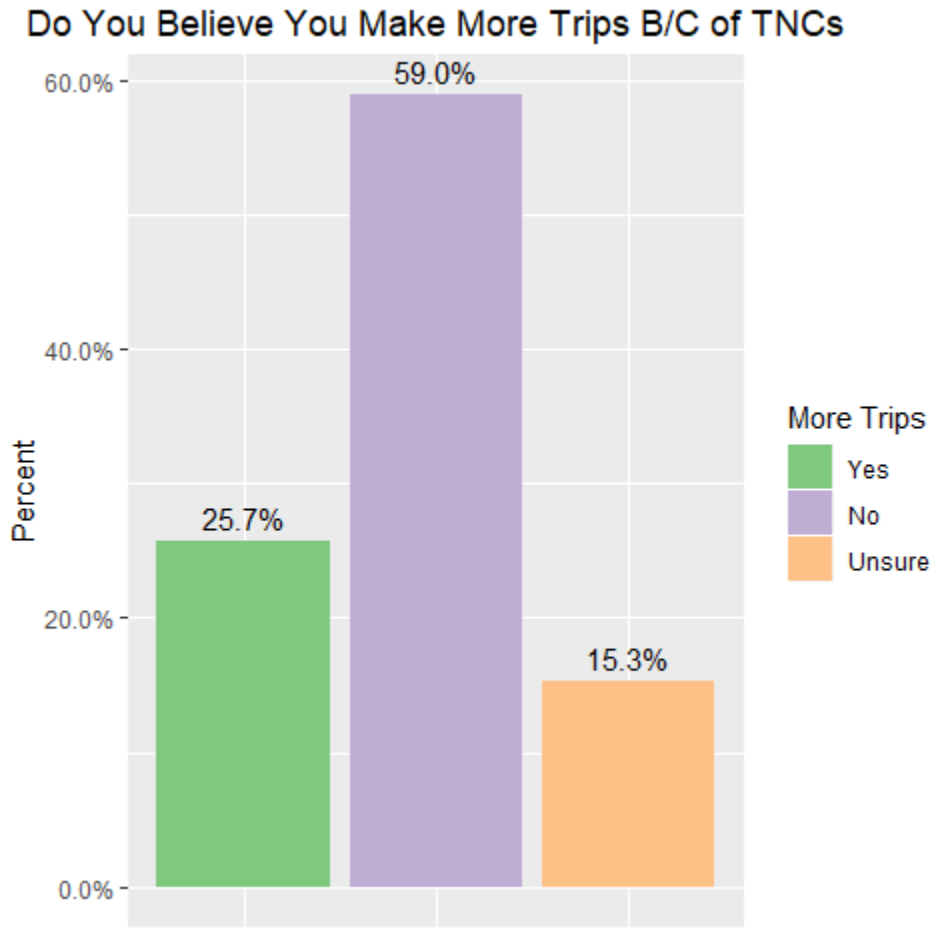

Figure 4.3: Perceived Trip Generation in Snowball Survey

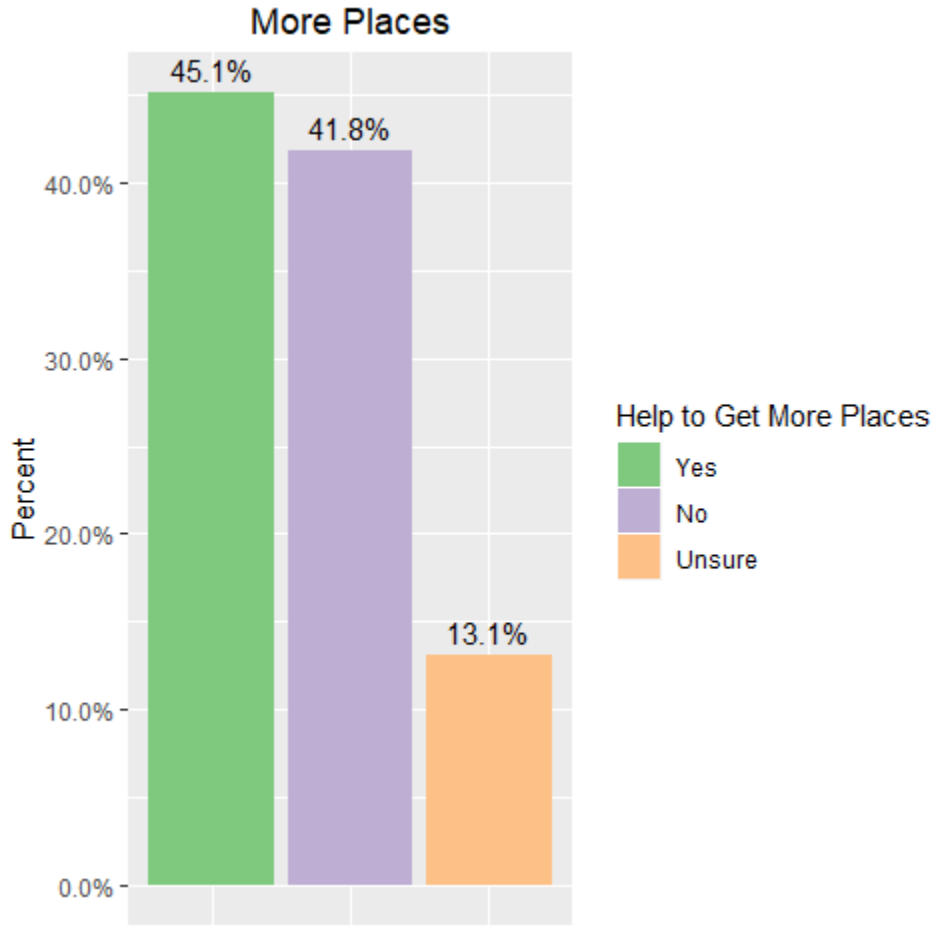

Figure 4.4: Perceived Access in Snowball Survey

4.2 QuestionPro Survey Results

As discussed in the Methods section the results of the snowball survey were used to inform the design of a survey using the professional survey company called QuestionPro. The same data cleaning approach was used for this survey. All incomplete responses were omitted and any respondent who did not specify a gender or ethnicity was excluded in order

to make interpretation of the results easier. Overall we collected 1000 complete responses, 250 responses were from each metro area (Austin, Dallas, Houston, and San Antonio). After cleaning there were 983 responses left.

4.2.1 QuestionPro Demographics

In Table 4.4 the demographic results for the QuestionPro survey are displayed. The demographics of the survey are somewhat different than would be expected based on American Community Survey (ACS) 2017 5 year data. However, the data collected cannot be directly compared to ACS data as our survey only includes those age 18 and older. Some of the data for ACS includes all people in the MSAs and cannot be disaggregated by age.

The largest age group was 26-30, but no one group is dominant in the QuestionPro survey. According to the ACS, the largest age group among those 18 years and older is those 55+ (29%).

Additionally, racial demographics are slightly different than the ACS indicates it they might be. In the QuestionPro survey 52% of respondents self-identify as White and 23% of respondents as Hispanic or Latino, the next largest group. According to ACS data 42.6% of the population, 18 years and older are White Alone and not Hispanic or Latino. While 35.3% of people in the four MSAs identify as Hispanic or Latino according to the 2017 ACS.

Interestingly, the respondents to this survey were also overwhelming female with 71% of survey takers stating they are female. In the four MSAs only 51% of those 18 and older are female, according to the ACS. This, along with the results of the snowball survey, might indicate that TNC users tend to be female. However, it may also indicate that women are more likely to participate in online surveys.

A plurality of respondents, 26.5%, made less than $25,000 last year. Compared to ACS data 18% of households in the four MSAs made less than $25,000 last year. The next most common response was $25,000 to $34,999 at 15%. Only 9% of households in the ACS data made that much last year. Only 4% of respondents indicated they made $150,000 or more last year. In the ACS data 14% of households made that much. However, again, this data is not directly comparable as the ACS collects income data at the household level and this survey asked individual respondents their income.

In terms of education, a near majority of respondents (45%) of respondents had some college. ACS data indicates that for those 25 and older 28% of the population in the four MSAs had some college. The second largest category after some college was a bachelors degree.

4.2.2 QuestionPro Usage Characteristics

The usage patterns of the Questionpro survey takers are remarkably similar to those of the snowball survey takers which indicates that there is a consistent pattern to TNC usage. This is shown in Table 4.5. Again we see that most users are using TNCs for occasional, recreational trips to bars and/or other entertainment venues. A pluarility of users (42.6%) of users are using TNCs less than once a month and like the snowball survey, a clear majority of users are using them once a month of less. Additionally, we see that most respondents use them for medium length trips 11-15 minutes and use them for trips on non-work days.

4.2.3 Perceptions of Services

Similar to the snowball survey when asked what they value most about TNCs respondents choose safety as the most important factor, followed by reliability. In terms of motivation, again users overwhelming reported (59%) that they were motivated by convenience. Although this number was lower than the snowball survey. The next most common choice was safety.

4.2.4 QuestionPro Relationship to Other Transportation Services

Just like in the snowball survey we asked users how they used TNCs to interact with other modes of transportation and how they perceived TNCs as compared to conventional taxis and public transport. The results are shown in Table 4.6. The results are very similar the snowball survey findings. As we can see most respondents find that TNCs are more convenient than conventional taxis and public transport with 79.8% and and 69.2% of respondents choosing this option respectively. Just like the snowball survey TNCs are considered more expensive than public transport, but cheaper than conventional taxis. Mirroring the snowball survey most respondents, 42.6% of them do not use TNCs to connect to other transportation modes. However, a fair percentage of respondents use TNCs to connect to 'other' forms of transportation or to connect to parked personal vehicles which is different than our snowball survey findings.

4.2.5 QuestioPro Perceived Trip Making

Finally our survey asked users about their perceived trip making activity with regards to TNCs. These results are shown in Figures 4.5 and 4.6 These results differ somewhat from

the results of the snowball survey. In this survey we find that 47.4% of respondents think that they make more trips because of TNCs. This is in contrast to the snowball survey where the clear majority of respondents thought that they did not make more trips because of TNCs. Additionally, a higher number of people (60.5%) thought that TNCs helped them to access more places.

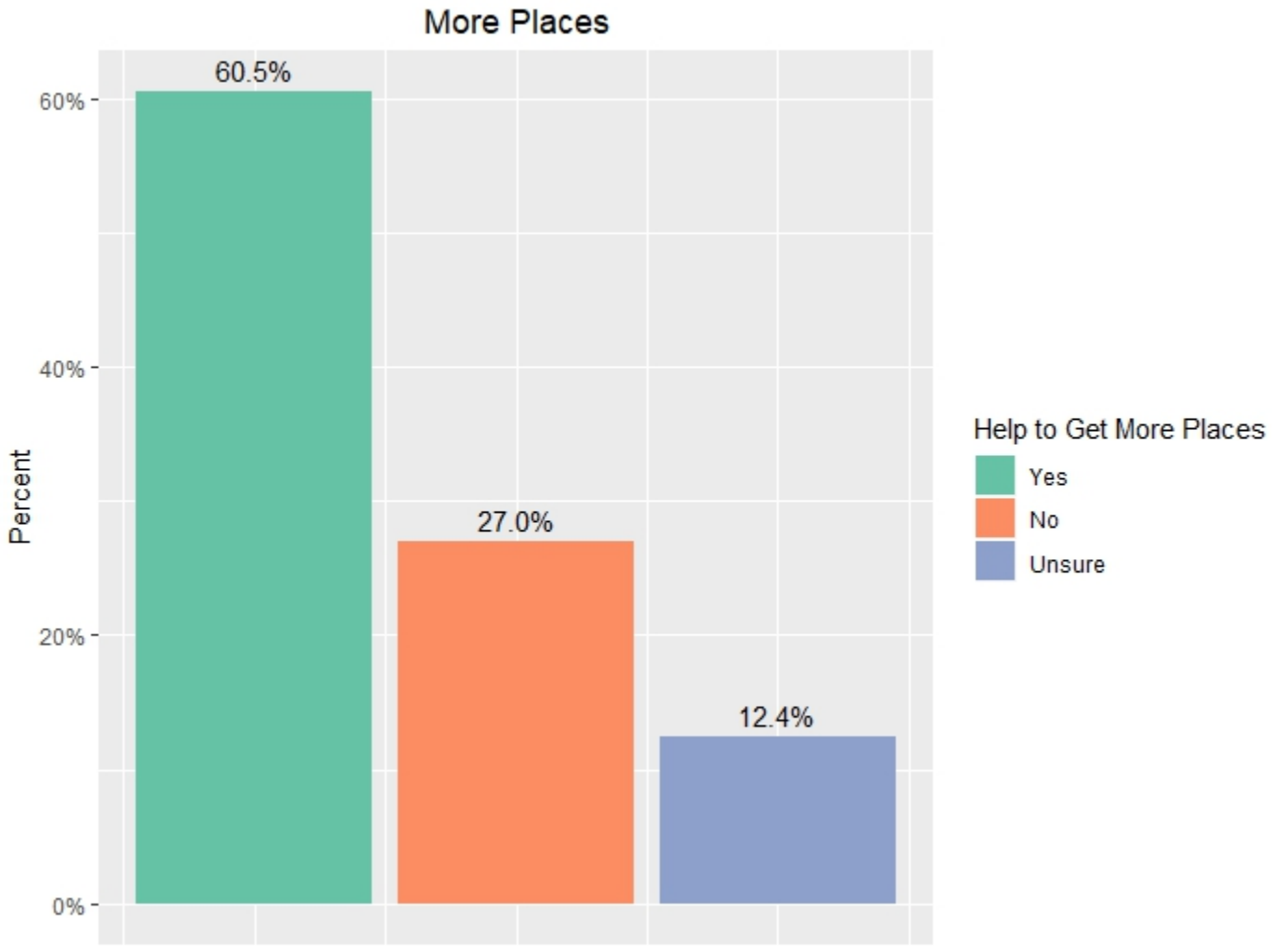

Figure 4.5: Perceived Access in QuestionPro Survey

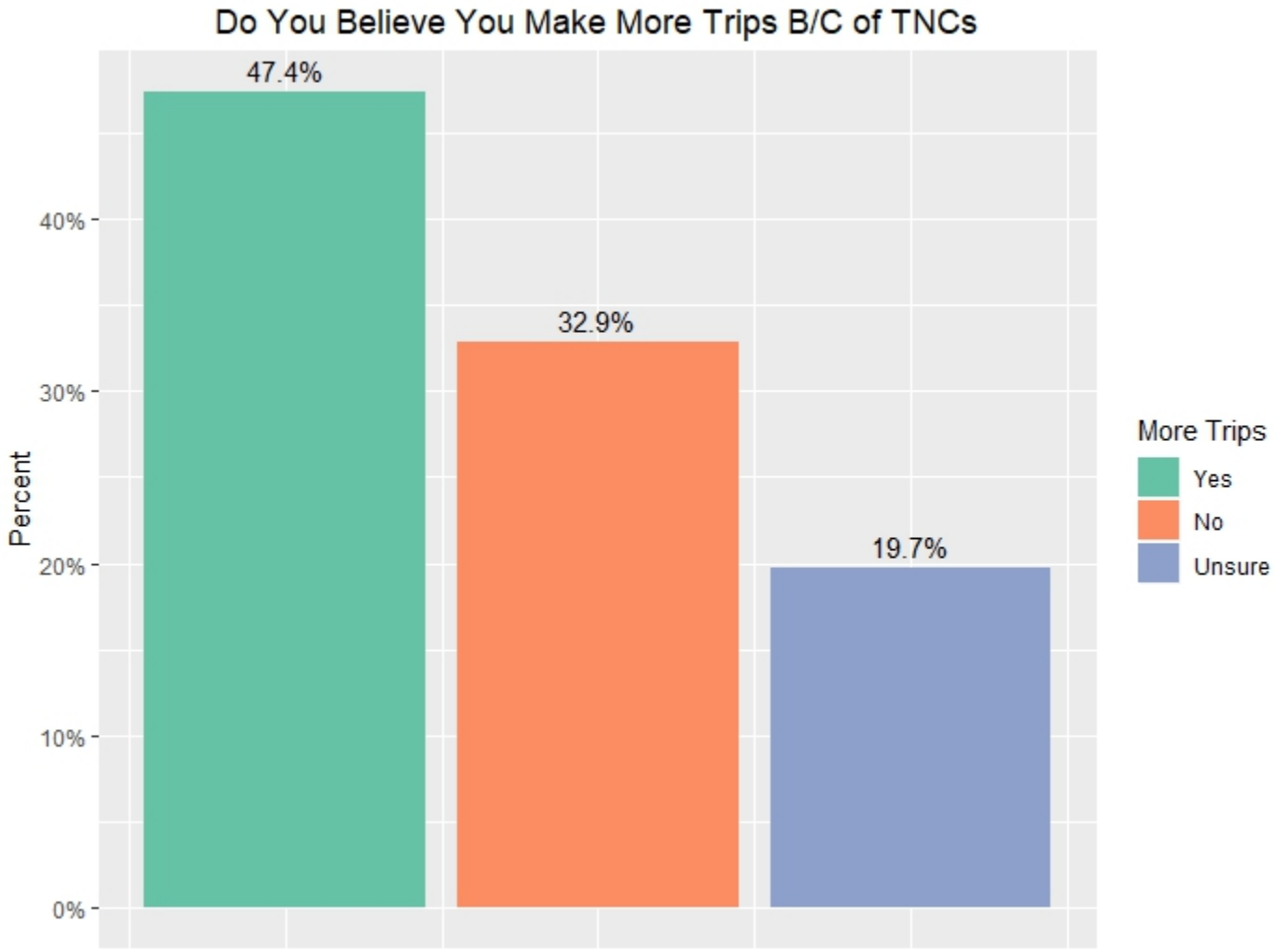

Figure 4.6: Perceived Access in QuestioPro Survey

4.3 Trip Generation Model Results

Moving on from the survey results, NhtbS 2017 data was used to further examine the question of whether TNCs are inducing travel demand among users.

The results of the two NB models are shown in Table 4.7. Working from home status, carshare usage, bikeshare usage, and family income do not have a significant influence on the number of trips on weekends. However, work from home status does influence the number of trips made during weekdays.

Most of these results make intuitive sense. Working from home would not influence the number of trips that a person makes on the weekend as most likely these people are not likely to be working anyway on the weekend. Income would not have a significant influence because regardless of income a person must commute to work. One possible explanation for the carsharing variable is that these services are relatively expensive to use and also require users to register with the service, have insurance etc. [102]. Thus, they may only be used when a special need arises and thus most trips are occasional in nature. In terms of bikesharing most research indicates that these services are used as a substitute for walking, riding public transport etc. [56]. This would make sense as these services as likely attractive to those already inclined to use active transportation modes especially because their are inherent limits to bikesharing as compared to cars.

All other variables did have a significant impact on the number of trips made. Interestingly, full time work status had a negative relationship with the number of trips made, but this does make sense as full time workers inherently have less time to make trips and thus likely limit their non-work trips to weekends. We also see that RIDESHARE, our primary variable of interest, had a significant impact for both weekends and weekdays. However, the relationship was significant at a slightbly higher confidence level for weekdays than weekends. The distinction between the confidence levels (99.999% and 99.99%) is so small as to not warrant further discussion. Finally, one interesting result is that TIMETOWK (time to work)

has an impact on both weekends and weekdays. There are at least two possible explanation for this. First, not everyone works during weekdays and thus some people are making work related trips on weekends. Second, workers who have longer commutes during weekdays may be disinclined to make trips during weekends as they desire time to rest and recreate at home.

Table 4.1: Snowball Survey Demographics

Demographic Variable	Number of Responses	Percent of Responses
Age?		
Under 18	0	0.0%
18-22	59	22.0%
22-25	42	15.7%
26-30	55	20.5%
31-35	38	14.2%
36-45	41	15.3%
46-55	16	6.0%
55+	17	6.3%
Ethnicity		
White	164	61.2%
African American or Black	7	2.6%
Hispanic or Latino/a	38	14.2%
Asian or Pacific Islander	50	18.7%
Other	9	3.4%
Prefer not to say	0	0.0%
Education		
Some high school or less	0	0.0%
High School Diploma or equivalent (GED)	9	3.4%
Some college, no diploma (4)	48	17.9%
Associate's or Vocatinal degree	82	30.6%
Bachelor's degree	76	28.4%
Master's degree	4	1.5%
Doctral or Professional degree (JD, MD, PhD, etc.)	49	18.3%
Vehicle Access		
Yes	209	78.0%
No	59	22.0%
Income		
less than $25,000	107	39.9%
$25,000 to $34,999	29	10.8%
$35,000 to $44,999	17	6.3%
$45,000 to $54,999	28	10.4%
$55,000 to $74,999	19	7.1%
$75,000 to $99,999	16	6.0%
$100,000 to $149,999	20	7.5%
$150,000+	32	11.9%
Sex		
Male	104	38.8%
Female	164	61.2%
Prefer not to say	0	0.0%

Table 4.2: Snowball Survey Usage Characteristics

Usage Variable	Number of Respondents	Percentage of Respondents
Approximately how often do you use ride-hailing services like Uber or Lyft?		
Less than once a month	91	34.0%
Once a month	55	20.5%
A few times a month	91	34.0%
Once a week	18	6.7%
2-3 times per week	13	4.9%
Daily	0	0.0%
More than once a day	0	0.0%
Which of the following most accurately describes your usage of ride-hailing services like Uber or Lyft? (check all that apply)		
Use for commuting to work/school	42	15.7%
Use for trips to bars, restaurants, and other entertainment venues	194	72.4%
Use for errands or personal business	44	16.4%
Use to connect to other transportation services (trains, airport, bus etc.)	105	39.2%
Use for emergency situations	54	20.1%
Other	29	10.8%
What time of day do you use ride-hailing services like Uber or Lyft? (choose all that apply)		
Early Morning (5 am - 7 am)	65	24.3%
Morning (8 am - 10 am)	77	28.7%
Early Afternoon (11 am - 1 pm)	55	20.5%
Afternoon (2 pm - 4 pm)	76	28.4%
Early Evening (5 pm - 7 pm)	122	45.5%
Evening (8 pm - 10 pm)	189	70.5%
Night (11 pm - 1 am)	155	57.8%
Late Night (2 am - 4 am)	83	31.0%
When do you primarily use ride-hailing services like Uber or Lyft?	90	33.6%
Work days	170	63.4%
Non-work days	8	3.0%
Holidays		
In your estimation, how long is your typical ride-hailing (Uber of Lyft) trip in minutes?		
Less than 5 mins	6	2.2%
5 - 10 mins	57	21.3%
10 - 15 mins	142	53.0%
15 - 20 mins	49	18.3%
20 mins or longer	14	5.2%

Table 4.3: Relationship Between TNCs and Other Transportation Modes

Transportation Relationship Variable	Number of Respondents	Percentage of Respondents
In your opinion compared to public transit ride-hailing services like Uber or Lyft are:		
More Convenient	222	82.8%
Less Convenient	13	4.9%
More Expensive	6	2.2%
Less Expensive	167	62.3%
More Reliable	120	44.8%
Less Reliable	13	4.9%
In your opinion, compared to traditional taxis ride-hailing services like Uber or Lyft are:		
More Convenient	220	82.1%
Less Convenient	13	4.9%
More Expensive	45	16.8%
Less Expensive	117	43.7%
More Reliable	129	48.1%
Less Reliable	19	7.1%
How often do you use ride-hailing services like Uber or Lyft to connect to another mode of transportation (such as a bus, rail line, personal vehicle, airport etc.)?		
Never	130	48.5%
Once a month	124	46.3%
A few times a month	9	3.4%
Once a week	3	1.1%
2-3 times per week	2	0.7%
Daily	0	0.0%
More than once a day		
If you use ride-hailing services like Uber or Lyft to connect to another mode of transportation, which mode do you most frequently connect to?		
Bus	18	6.7%
Rail line	10	3.7%
Parked vehicle	12	4.5%
Bicycle	1	0.4%
Other	109	40.7%
Airport	8	3.0%
I do not use these services to connect to other transportation modes	110	41.0%

Table 4.4: QuestionPro Demographics

Demographic Variable	Number of Responses	Percent of Respondents
Age		
Under 18	0	0.00%
18-22	149	15.16%
23-25	98	9.97%
26-30	185	18.82%
31-35	158	16.07%
36-45	211	21.46%
46-55	106	10.78%
55+	76	7.73%
Ethnicity		
White	519	52.80%
African American or Black	145	14.75%
Hispanic or Latino/a	234	23.80%
Asian or Pacific Islander	60	6.10%
Other	25	2.54%
Prefer not to say	0	0.00%
Gender		
Male	283	28.56%
Female	708	71.44%
Education		
Some high school or less	38	3.87%
High school diploma or equivalent (GED)	185	18.82%
Some college, no diploma	268	27.26%
Associates or vocational degree	148	15.06%
Bachelor's degree	239	24.31%
Master's degree	78	7.93%
Doctoral or Professional degree (PhD, MD, JD, etc.)	27	2.75%
Vehicle Access		
Yes	862	87.69%
No	121	12.31%
Income		
less than $25,000	261	26.55%
$25,000 to $34,999	148	15.06%
$35,000 to $44,999	100	10.17%
$45,000 to $54,000	115	11.70%
$55,000 to $74,000	131	13.33%
$75,000 to $99,999	103	10.48%
$100,000 to $150,000	85	8.65%
$150,000+	40	4.07%

Table 4.5: Usage Patterns for QuestionPro Survey Takers

Usage Variable	Number of Responses	Percent of Responses
Frequency of Use		
Less than once a month	419	42.62%
Once a month	155	15.77%
A few times a month	257	26.14%
Once a week	38	3.87%
2-3 times a week	85	8.65%
Daily	19	1.93%
More than once a day	10	1.02%
Time of Day Used		
Early morning (5am-7am)	168	6.90%
Morning (8am-10am)	271	11.13%
Early afternoon (11am-1pm)	213	8.75%
Afternoon (2pm-4pm)	281	11.54%
Early evening (5pm-7pm)	388	15.93%
Evening (8pm-10pm)	487	20.00%
Night (11pm-1am)	409	16.80%
Late night (2am-4am)	218	8.95%
Primary Day of Week Used		
Work days	329	33.47%
Non-work days	581	59.10%
Holidays	73	7.43%
Length of Typical Trip		
Less than 5 minutes	32	3.26%
5-10 minutes	216	21.97%
11-15 minutes	360	36.62%
16-20 minutes	251	25.53%
21 minutes or longer	124	12.61%

Table 4.6: QuestionPro Transportation Relationship

Transportation Relationship Variable	Number of Respondents	Percentage of Respondents
Compared to Public Transport		
More Convenient	784	79.8%
Less Convenient	41	4.2%
More Expensive	275	28.0%
Less Expensive	116	11.8%
More Reliable	266	27.1%
Less Reliable	19	1.9%
Compared to Conventional Taxis		
More Convenient	680	69.2%
Less Convenient	46	4.7%
More Expensive	103	10.5%
Less Expensive	389	39.6%
More Reliable	297	30.2%
Less Reliable	23	2.3%
Frequency of TNC Use to Connect to Another Transportation Mode		
Never	419	42.6%
Once a month	155	15.8%
A few times a month	257	26.1%
Once a week	38	3.9%
2-3 times per week	85	8.6%
Daily	19	1.9%
More than once a day	10	1.0%
Most Frequent Mode Connect To		
Bus	124	12.6%
Rail Line	56	5.7%
Parked Vehicle	130	13.2%
Bicycle	9	0.9%
Other	268	27.3%
Airport	31	3.2%
I do not use these services to connect to other transportation modes	365	37.1%

Table 4.7: Results for NHTS Model Estimation for Shared Mobility Services

	Weekdays		**Weekends**	
Dependent Variable Name	Coefficient Estimate	Significance Code	Coefficient Estimate	Significance Level
Age	0.001	***	0.001	***
Education	0.042	***	0.033	***
Work from Home (Dummy)	0.052	***	0.005	
Carshare Usage	-0.002		0.000	
Bikeshare Usage	0.001		-0.000	
Rideshare Usage	0.003	***	0.005	**
Time to Work	-0.001	***	-0.000	**
Health Status	-0.026	***	-0.031	***
Population Density at Home	0.000	*	0.000	***
Worker Status (Dummy	0.038	***	0.036	***
Urban/Rural Status	0.030	***	0.048	***
Household Family Income	0.000		0.000	
Driver Status (Dummy)	0.203	***	0.155	***
Male (Dummy)	-0.036	***	-0.022	***
Full Time Worker (Dummy)	-0.102	***	0.039	***
Note: Sign. level: 0.0001: '***' 0.001: '**' 0.01: '*' 0.05: '.'				

Chapter 5

Discussion and Conclusions

Overall the goal of this study was to try and understand how people are perceiving and using TNCs. It analyzed two distinct sets of survey data and then analyzed the impact of shared mobility services on trip generation using NHTS 2017 datasets. In terms of the survey data the results between the two surveys are remarkably similar. The primary conclusion between both surveys is that most people are using TNCs for occasional, recreational travel. Both surveys found that most respondents use TNCs to go to bars, restaurants or other entertainment venues, use them primarily on non-work days, and in the evenings. Additionally, the majority of users use them only a few times a month or less. Such findings likely have serious implications for both planning practice and transportation policy which are discussed in detail below.

We can tentatively draw some conclusions about the overall demographics of TNC users from the surveys. We see, from the QuestionPro survey, that users are perhaps not as younger and affluent as people presume them to be. This perhaps indicates that as TNC services are become more widespread, as other studies have suggested, they are being utilized by a wider variety of citizens [117].

Interestingly, the vast majority of all respondents across both surveys found stated that they had regular access to a personal vehicle. This perhaps indicates that the concept

of "ridehail services such as Uber and Lyft...[revolutionizing] how people access cars" is overstated [99, para.1]. This makes some intuitive sense for at least three reasons. First, rough math indicates that TNCs are very expensive as compared to driving. Data from Sherpashare, a company that collects voluntary data from TNC drivers, found that the average TNC trip in the US, in 2015, was about 6 miles and that the average gross fare was about $12 [88, 143]. Dividing the cost by the miles yields a rough estimate of about 2 dollars per mile. The cost of driving a personal car is about ¢.60 per mile [11]. Thus it is very expensive to take a TNC as compared to a private vehicle. Second, the overall ability of these services to serve all users in a way that would make sense as a car replacement is likely not there yet. TNCs are still largely only available in urban areas and even in urban areas they are unevenly available [83]. Thus, users may not be willing to deal with the uncertainty of relying on TNCs for substantial portion of their transportation needs. Finally, private vehicles may simply offer the privacy and convenience (e.g. ability to easily transport groceries, ability to drive anywhere etc.) that TNCs do not offer.

In terms of perceptions of these services the surveys found similar things. Most users appear to value safety and reliability over travel time, cost, and comfort. Additionally, users are overwhelming motivated by convenience as compared to cost, travel time, or other factors. This finding is generally confirmed by the fact that TNC users view them as more convenient and reliable than public transport or conventional taxis. Thus users clearly seem to value the overall ease of use and general convenience that TNCs offer them. In this aspect TNCs do have inherent advantages that public transport cannot compete with. They offer users direct-to-their-destination travel, they offer a fixed fare, and they may be quicker in some circumstances than public transport. Additionally, wait times are likely lower during peak

TNC usage times (nights, weekends) than public transport.

The results of the NB models show that TNC services do appear to have an influence on the number of trips a person makes on both weekends and weekdays. Thus, they appear to be inducing at least some travel demand for users of these services. Additionally, in both surveys a significant percentage of people thought that they made more trips because of TNCs, although the QuestionPro survey had far more respondents (47.4%) state they thought that TNCs caused them to make more trips than the snowball survey (25.7%). However, overall, it would not be unreasonable to state that some at least some significant portion of TNC users are induced to make more trips because of the availability of these services.

This induced travel demand, along with the fact that many TNC users own personal vehicles, implies that TNCs might be worsening road congestion. Users seem to be keeping their personal vehicles, likely for daily commuting etc. but taking TNCs for supplemental purposes such as trips to bars. From a planning and policy perspective cities might have to consider how best to manage this induced travel demand. First and foremost cities should honestly assess how many TNCs they want operating in their cities and be honest about the potential induced travel demand. Accounting for induced travel demand in travel models is important because "Changes in the structure of demand...will have influence on development patterns" at common origins and destinations" [63, pg.15]. TNCs may also be somewhat unique in that induced travel demand may largely be due to the convenience of the service offered and not reduced travel time as much induced travel demand is [98].

In addition to better accounting for induced travel demand and perhaps capping the number of vehicles that TNCs can make available in any given city cities might also consider why people are using TNCs as opposed to other services like public transport. Our

surveys largely indicate that people are using these services because they view them as more reliable and convenient than public transport. Thus, cities should seriously consider if public transport could be improved to better compete with TNCs. This may difficult however, as most TNC users are using them at night when public transport is least likely to be available and to be at its most expensive in terms of cost per person. Therefore planners need to carefully consider the benefits and costs associated with encouraging or discouraging TNC service in their cities.

Finally, to some degree this study speaks to the future of TNCs. It is well known TNCs have not turned a profit to date [109]. Much of the hype and investor confidence around these companies was predicated on the idea that they were revolutionary technologies [17]. However, this has not really proven to be the case. Few people, in our study, seem to using them for daily trips or even using them with any sort of regularity. Thus, these companies may have trouble increasing their usage beyond a somewhat niche product for leisure travel. It would not be surprising, in this author's opinion, if Uber and Lyft merged in the next few years or perhaps ceased to exist altogether.

Appendix

Appendix 1

Survey Questions

1. Have you ever used a ride-hailing service like Uber or Lyft? (Yes/No)
2. What is your age? (Under 18; 18-22; 23-25; 26-30; 31-35; 36-45; 46-55; 55+)
3. What is your ethnicity? (White; African American; Hispanic or Latino; Asian or Pacific Islander; Other; Prefer not Say)
4. What is the highest level of education you have completed? (Some high school or less; High school diploma or equivalent (GED); Some college, no diploma; Associates or vocational degree; Bachelor; Master; Doctoral or Professional degree (PhD, MD, JD, etc))
5. Do you own or have regular access to a personal vehicle? (Yes/No)
6. What was your income last year? (Less than $25,000; $25,000 to $34,999; $35,000 to $44,999; $45,000 to $54,999; $55,000 to $74,999; $75,000 to $99,999$100,000 to $149,999; $150,000+)
7. What is your sex? (Male; Female; Prefer not Say)
8. Which of the following cities do you live in or closest to? (Austin; Dallas-Fort Worth; Houston; San Antonio)

9. Approximately how often do you use ride-hailing services like Uber or Lyft? (Less than once a month; Once a month; A few times a month; Once a week; 2-3 times a week; Daily; More than once a day)

10. Which of the following most accurately describes your usage of ride-hailing services like Uber and Lyft? (Check all that apply) (Use for commuting to work or school; Use for trips to bars, restaurants, and other entertainment venues; Use for errands or personal business; Use to connect to other transportation services (trains, airport, bus, etc. . .); Use for emergency situations; Others)

11. What time of day do you use ride-hailing services like Uber and Lyft (check all that apply)? (Early morning 5-7am; Morning 8-10am; Early afternoon 11-1pm; Afternoon 2-4pm; Early evening 5-7pm; Evening 8-10pm, Night 11-1am; Late night 2-4am)

12. When do you primarily use ride-hailing services like Uber and Lyft? (Workdays; Non-work days; Holidays)

13. In your estimation, how long is your typical ride-hailing (Uber/Lyft) trip? (Less than 5 minutes; 5-10 minutes; 11-15 minutes; 16-20 minutes; 21 minutes or longer)

14. How often do you use ride-hailing services like Uber or Lyft to connect to another mode of transportation (such as a bus, rail line, personal vehicle, airport etc.)? (Never, Once a month; A few times a month; Once a week; 2-3 times a week; Daily; More than once a day)

15. If you use ride-hailing services like Uber or Lyft to connect to another mode of transportation, which mode do you most frequently connect to? (Bus; Rail Line; Parked

personal vehicle; Bicycle; Airport; Other; I do use these services to connect to other transportation modes)

16. How important are the following factors to you when using ride-hailing services like Uber and Lyft?

    16.1. Cost; Not important; Slightly important; Neutral; Important; Extremely Important

    16.2. Reliability of service; Not important; Slightly important; Neutral; Important; Extremely Important

    16.3. Travel time; Not important; Slightly Important; Neutral; Important; Extremely Important

    16.4. Safety; Not Important; Slightly Important; Neutral; Important; Extremely Important

    16.5. Comfort; Not Important; Slightly Important; Neutral; Important; Extremely Important

17. What is your primary motivation for using ride-hailing services like Uber/Lyft? (Cost; Convenience; Total travel time; Safety; Other)

18. In your opinion, compared to public transit, ride-hailing services like Uber and Lyft are: (More convenient; Less convenient; More expensive; Less expensive; More reliable, Less reliable)

19. In your opinion, compared to traditional taxis, ride-hailing services like Uber and Lyft are: (More convenient; Less convenient; More expensive; Less expensive; More reliable, Less reliable)

20. Do you believe you make more trips because of ride-hailing services like Uber and Lyft? (Yes; No; Unsure)

21. Do you believe that ride-hailing services like Uber and Lyft help you go to places that you would not otherwise go to if Uber/Lyft did not exist? (Yes; No; Unsure)

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